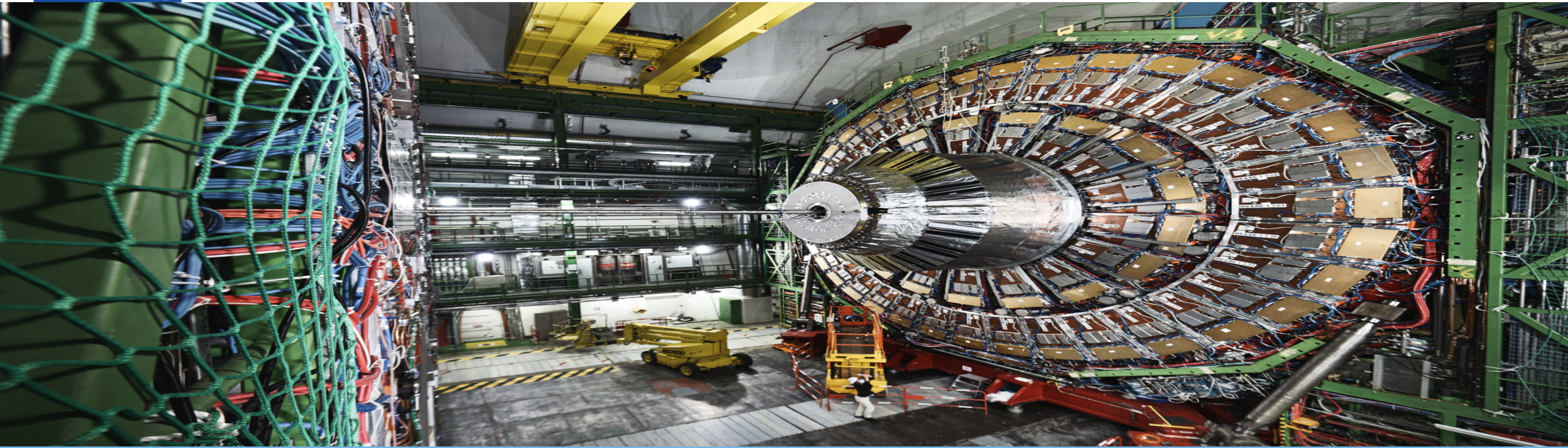
Eleuterio Spiriti on behalf of the TIIMM group

Istituto Nazionale di Fisica Nucleare



WP27-JRA9

Tracking and Ions Identifications with Minimal Material budget

(TIIMM)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

Talk overview

1. Remind of the workpage goals

   verified cluster size dependence from charge released in MAPS

   fully depletion could improve charge measure resolution

2. Accomplished activities (main achievements)

   TIIMM0 construction and test

3. Activities underway
4. Deliverables and milestones status
5. Summary: difficulties, delays, future planning

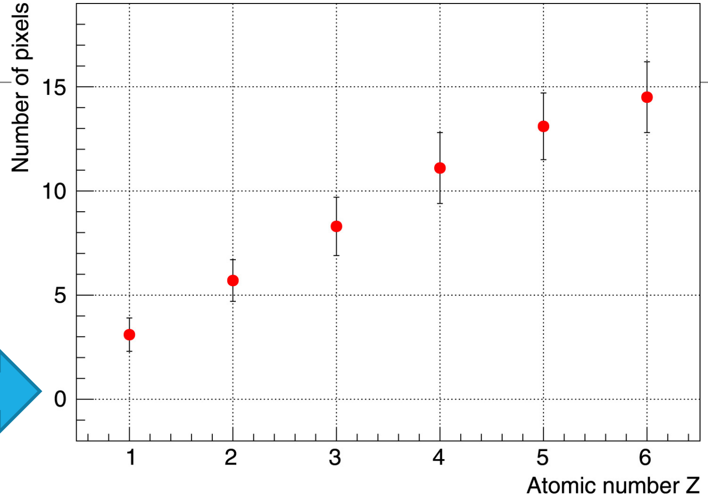
Remind of the workpage goals

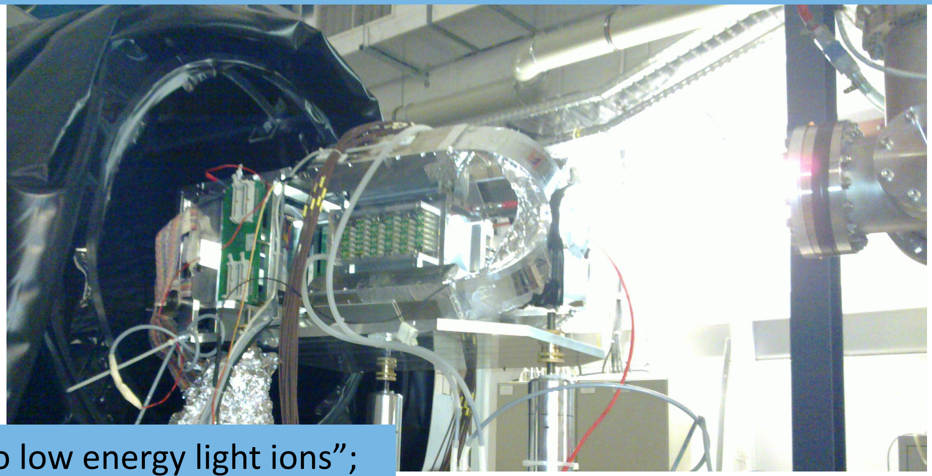
dE/dx in existing MAPS: where do we stand.

FIRST (Fragmentation of Ions foR Space and Therapy)

M. Toppi et al., "Measurement of fragmentation cross sections of C ions on a thin gold target with the FIRST apparatus," Phys. Rev. C, vol. 93, no. 6, p. 064601, 2016.

Number of pixel per cluster vs ion atomic number in FIRST data taking at GSI.
Measured in the MAPS (M26) vertex detector .



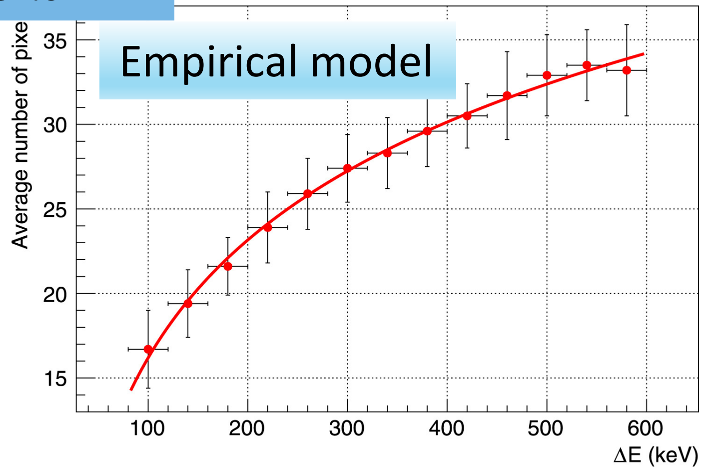


E. Spiriti et al.,"CMOS active pixel sensors response to low energy light ions"; Nuclear Inst. and Methods in Physics Research. A 875C (2017) pp. 35-40

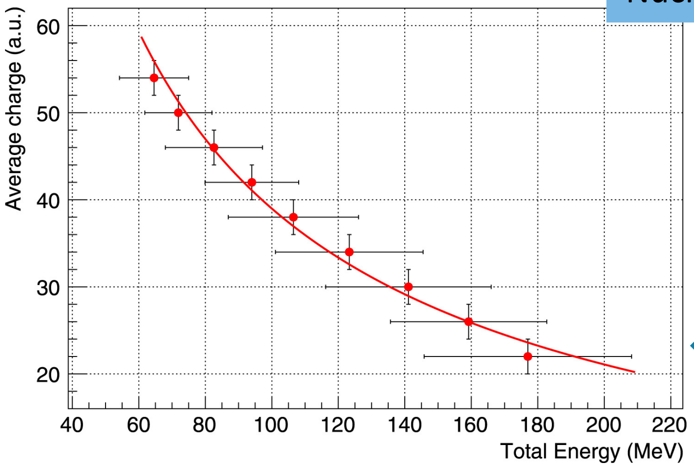
$$n_p = \frac{\pi r_T^2}{p^2} = 2\pi r_s \mathrm{Log}\left(\frac{\Delta E}{2\pi E_g T_s}\right)$$

$r_s = \sigma^2/p^2$ and $T_s = T\sigma^2$ (only two parameters)
σ = spread of Gaussian charge diffusion, T = single pixel charge threshold

Empirical model



Measured (M18 sensor) released charge in 14 μm thick silicon epitaxial layer *vs* total ion (Z=2) energy (measured in CsI telescope).

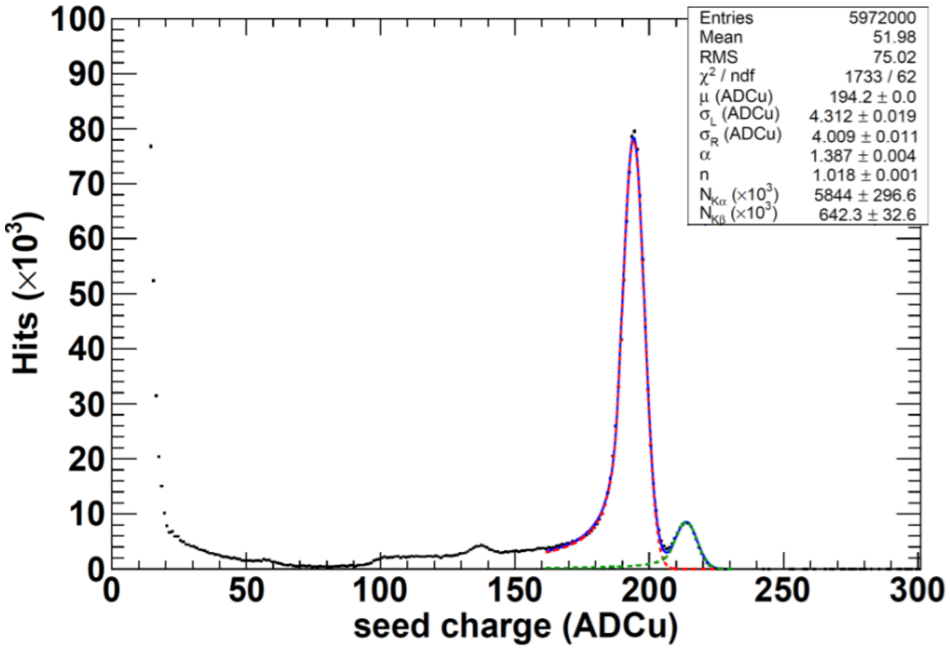


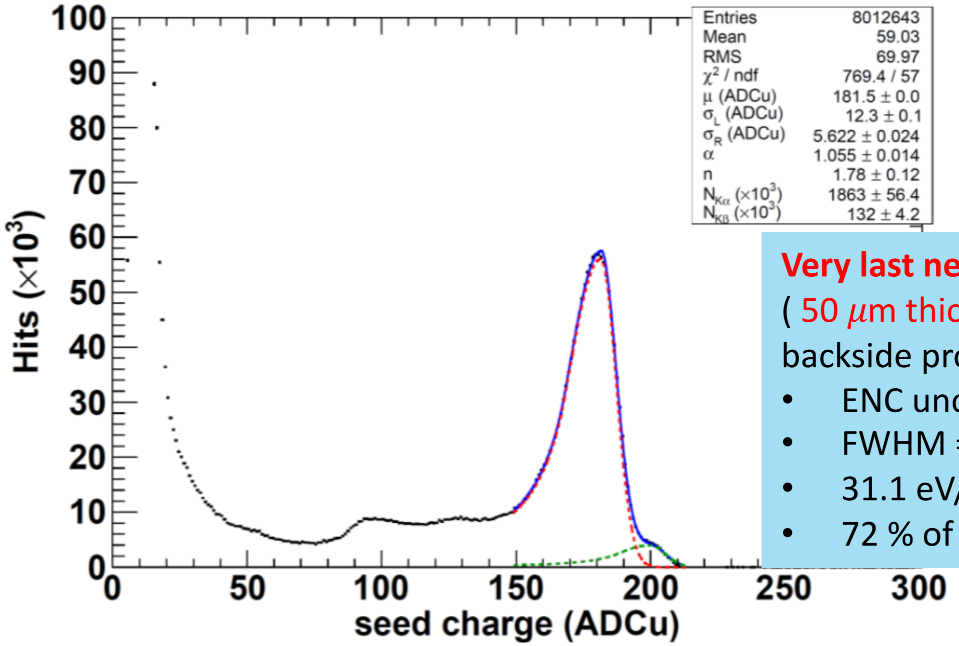
Remind of the workpage goals

After clustering ➔ Seed pixel charge distribution

- **18 μm thick epitaxial layer (HR18)**
  - ❑ ENC = 24 e^-
  - ❑ FWHM (5.9 keV) = 298 eV
  - ❑ 30.38 eV/ADCu
  - ❑ Si escape peak visible (138 ADCu)
  - ❑ 75 % of the charges collected on the seed pixel on average
- **280 μm thick Czochralski (CZ)**
  - ❑ ENC = 26 e^-
  - ❑ FWHM (5.9 keV) = 686 eV
  - ❑ 32.51 eV/ADCu
  - ❑ Mn-Kα and Mn-Kβ merging
  - ❑ 68 % of the charges collected on the seed pixel on average

J. Heymes ; "Performances of depleted Monolithic Active Pixel Sensor in a high-resistivity CMOS process for X-ray detection", slide, 11th International Conference on Position Sensitive Detectors PSD2017, Milton Keynes, the UK, 3-8 September 2017





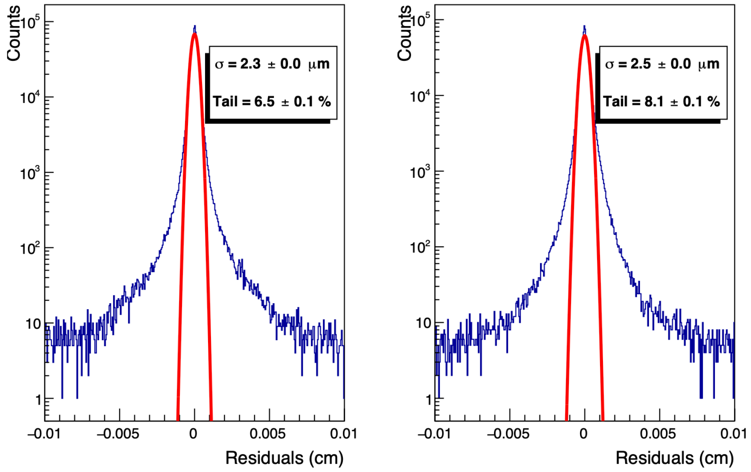
Very last news (preliminar)!
(50 μm thick, CZ silicon, backside processed, 30V bias)
- ENC unchanged
- FWHM = = 350 eV
- 31.1 eV/ADCu
- 72 % of charge on seed pixel

Pipper-2 measurements (presc. 2, T°_{cool}=7 °C, V_{diode}=30V) ^{55}Fe irradiation – 400000 frames

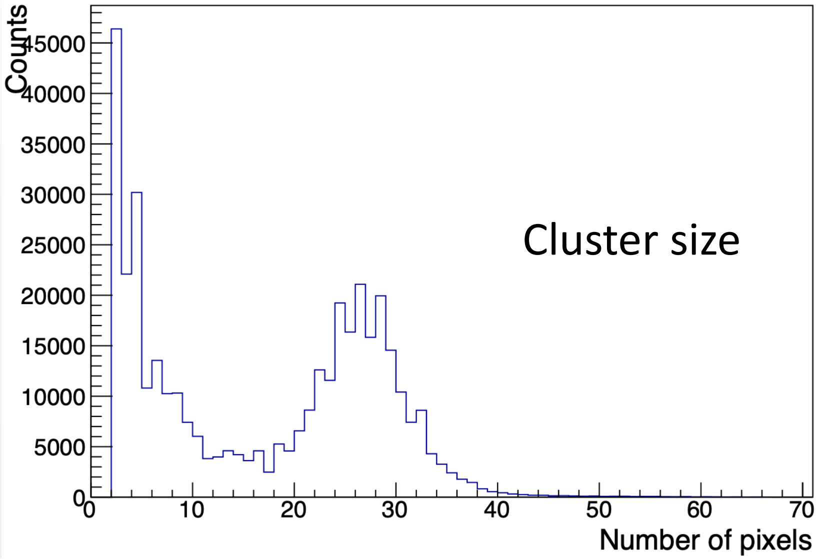
Remind of the workpage goals

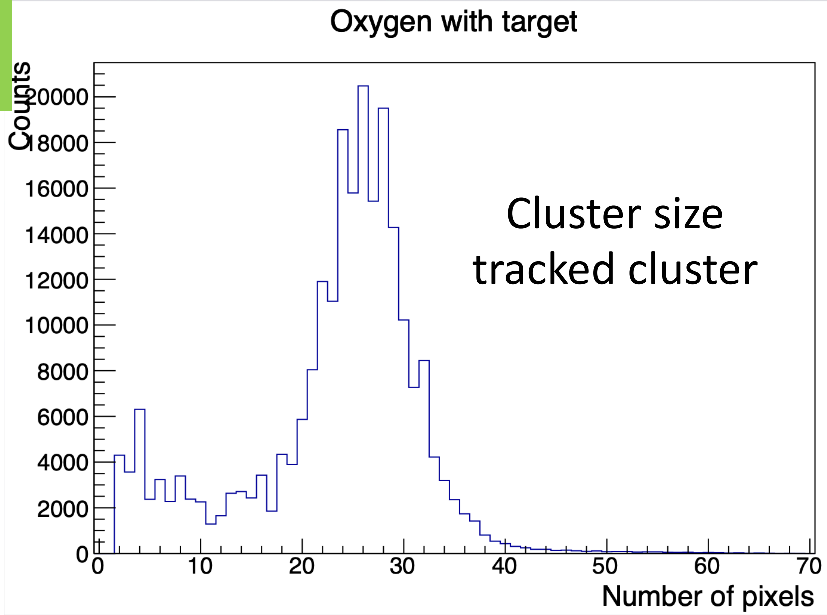
Precision Tracking (few μm obtained)	+	Low material Budget (0.3 % X_0 achieved)	+	Energy loss measurement (still missing on large area)

VTX alignment residuals (cluster size > 20):

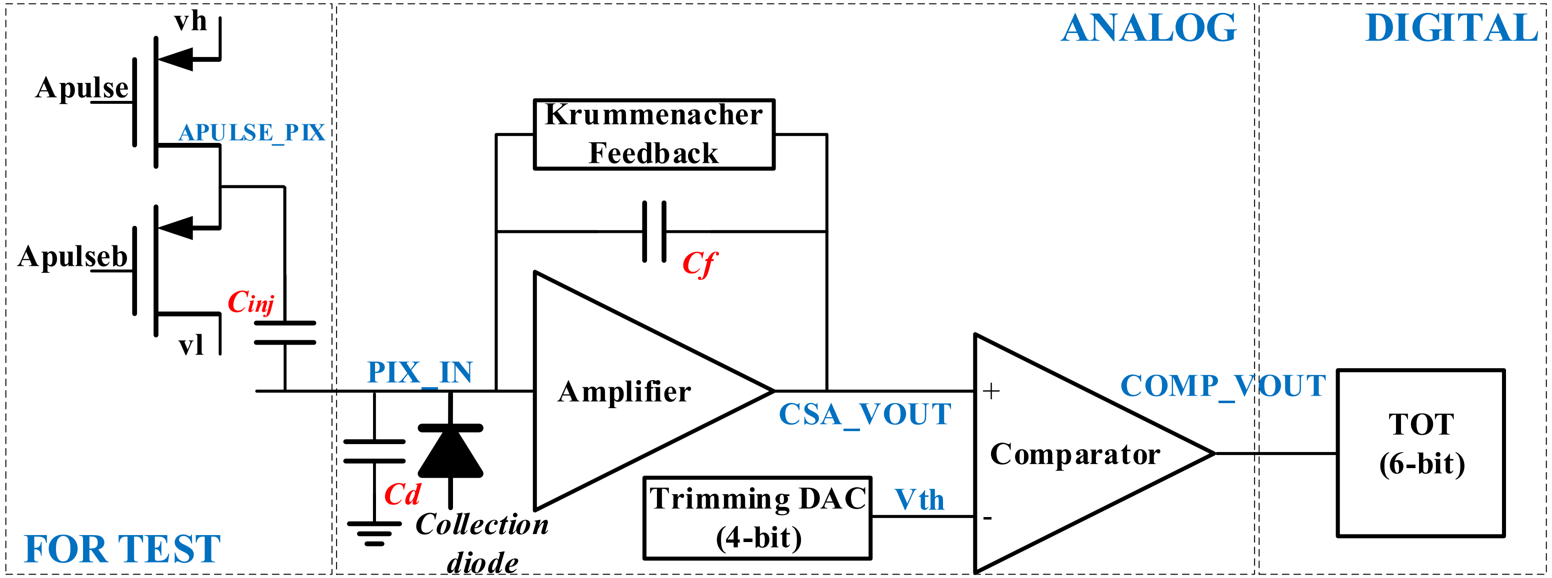


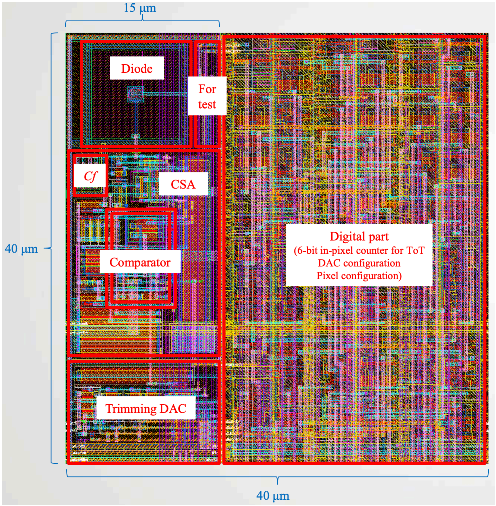
FOOT-Vertex data with Oxygen beam @GSI july 2021 (Courtesy C.Finck, FOOT collaboration)





Accomplished activities - TIIMM-0 prototype





TIIMM-0

Pixel pitch: 40µm

C_f: 1fF

TOT (6 bits)

Trimming DAC (4 bits)

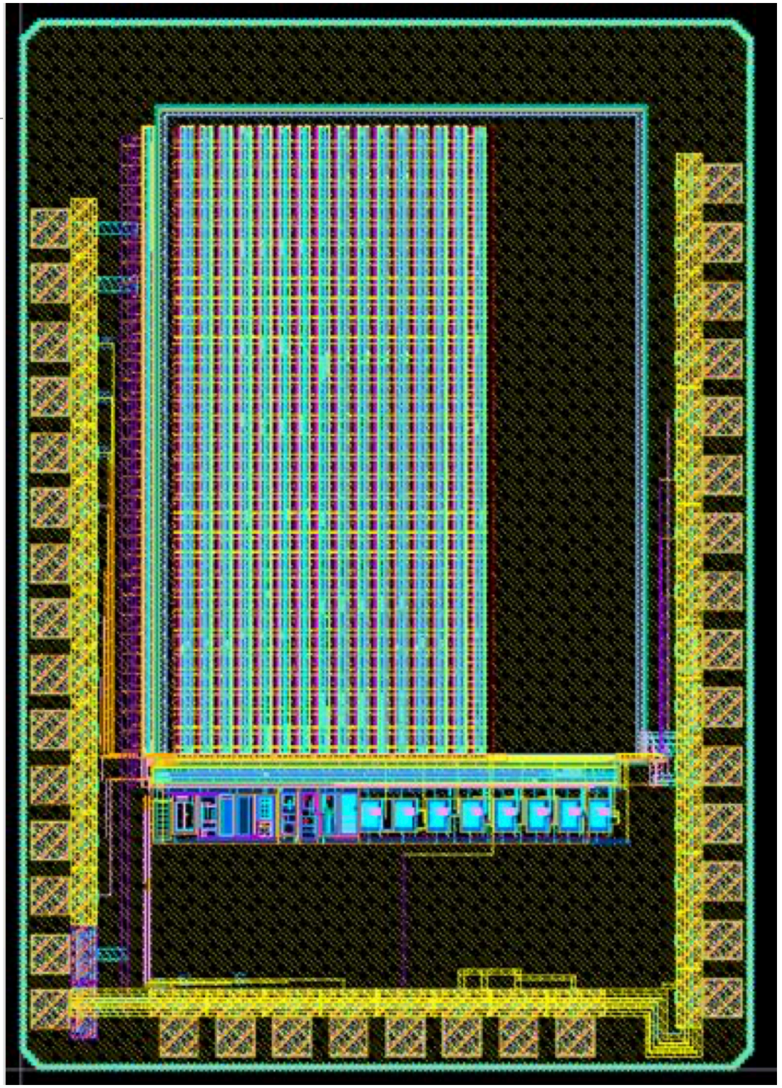
ENC: 42 e^-

Matrix: 32 rows x 16 columns

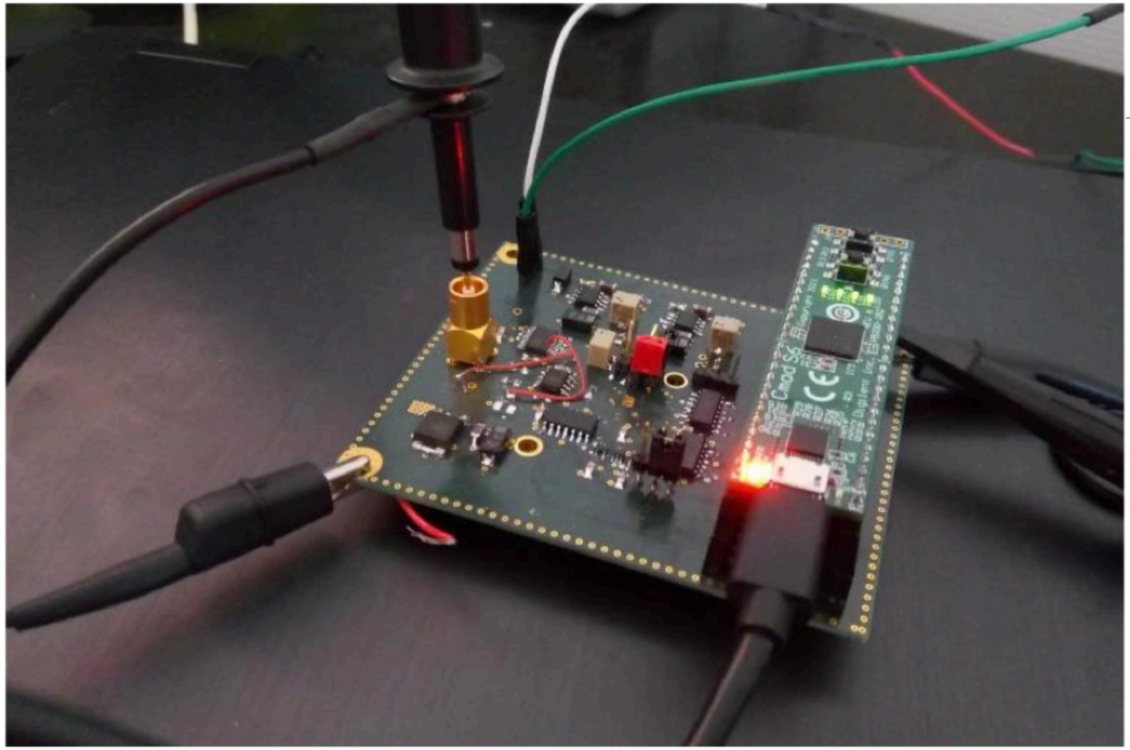
+1 column with analogue out

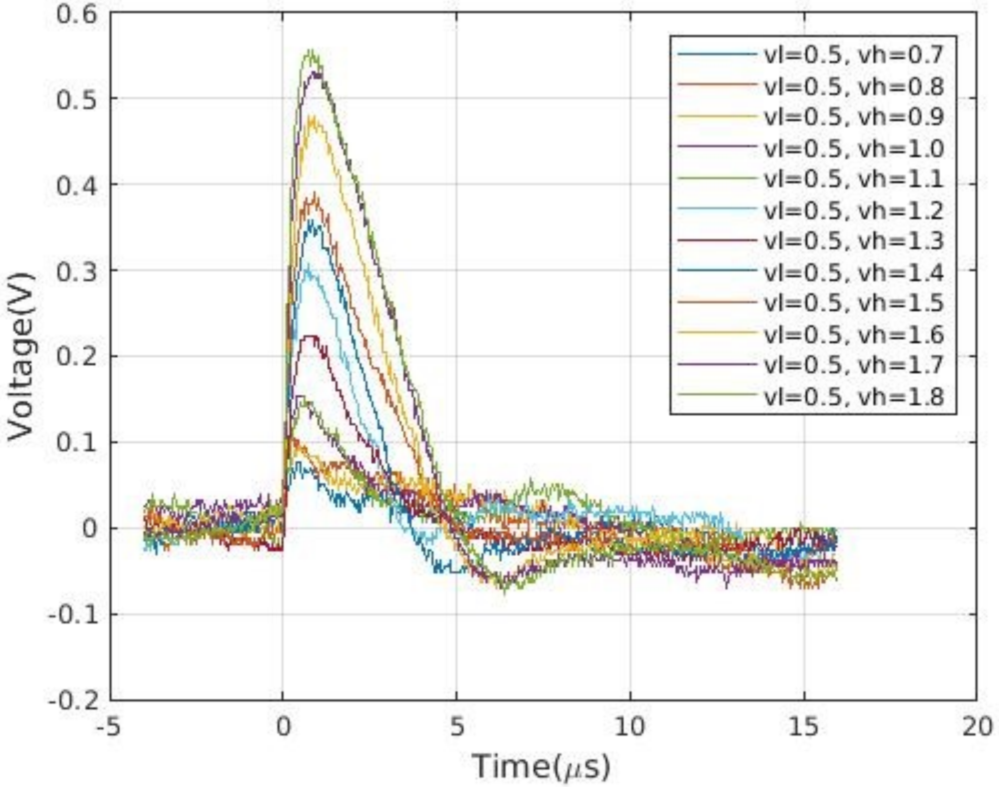
Chip area: 2.2 mm * 1.5 mm

Position and energy measurements



Accomplished activities - TIIMM-0 prototype





Analogue output of the CSA with different input charge

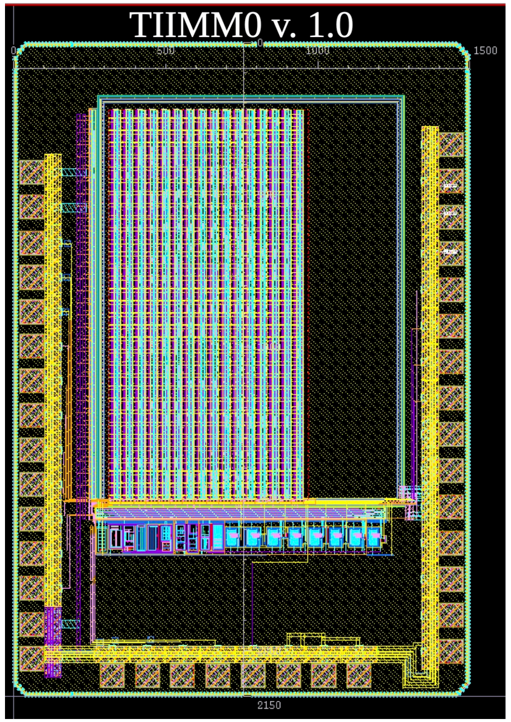
SETUP

- **CMODS6 Digilent module (FPGA)**
- **Tektronix TDS5054 scope**
- **Keithley 237 current source**

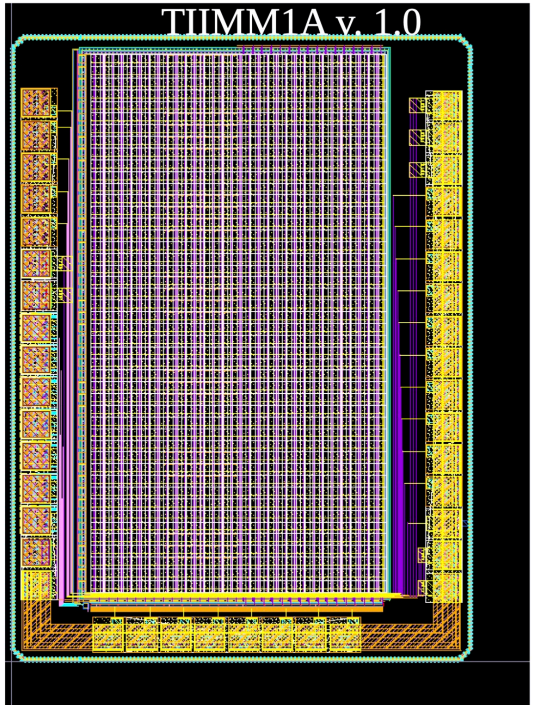
Some bugs in the pulsing circuitry and in the on-chip DAC settings circuitry prevented any reasonable test on beam.
Waiting for TIIMM1 prototypes to make further tests.

Activities underway: TIIMM-1 prototype

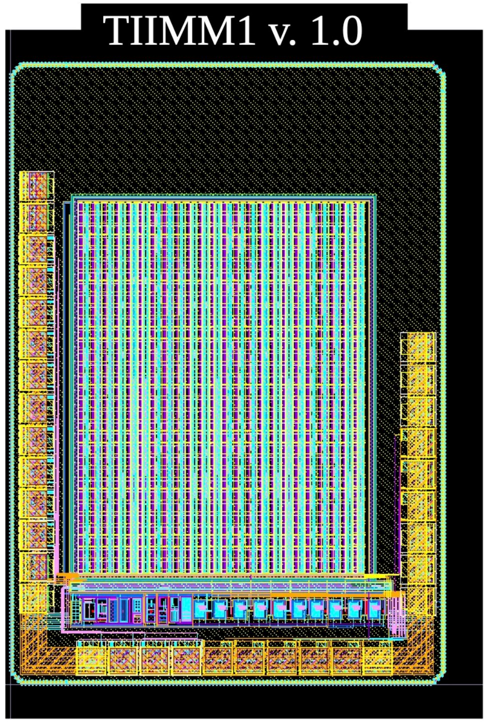
Starting from the TIIMM-0 experience we designed three versions of the new sensors to be tested separately.
Submission to silicon foundry those days in **3 different epitaxial layer thickness 25μm 50μm and 100μm**.



Corrected version of TIIMM0

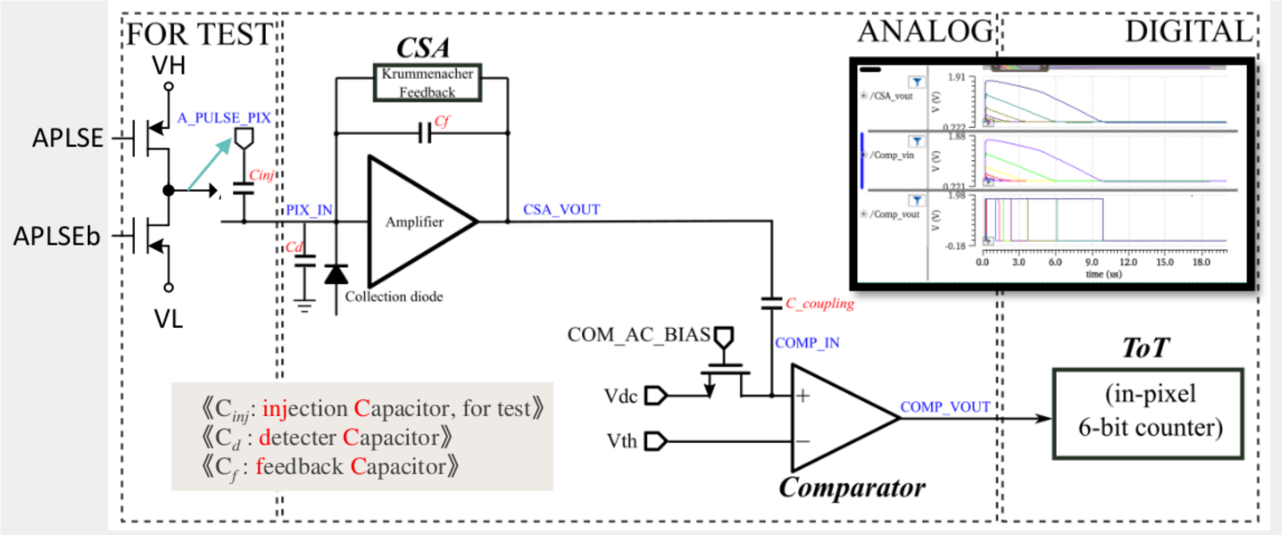


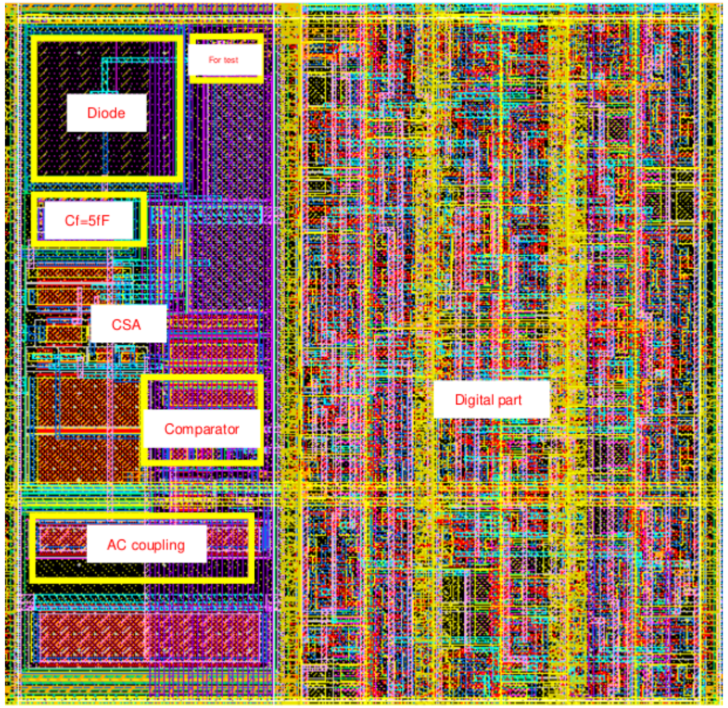
TIIMM1A pixel analog front-end only (see presentation by W.Ren at PSD2021)

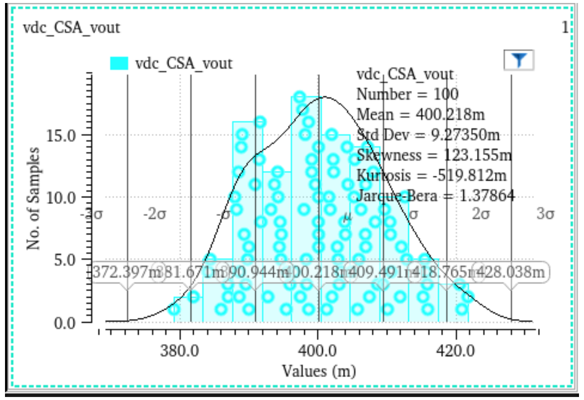


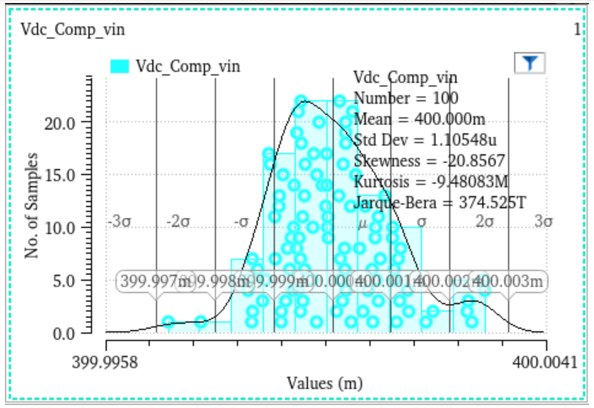
TIIMM1 full version with new analog front-end enlarging the dynamic range

Activities underway: TIIMM-1 prototype







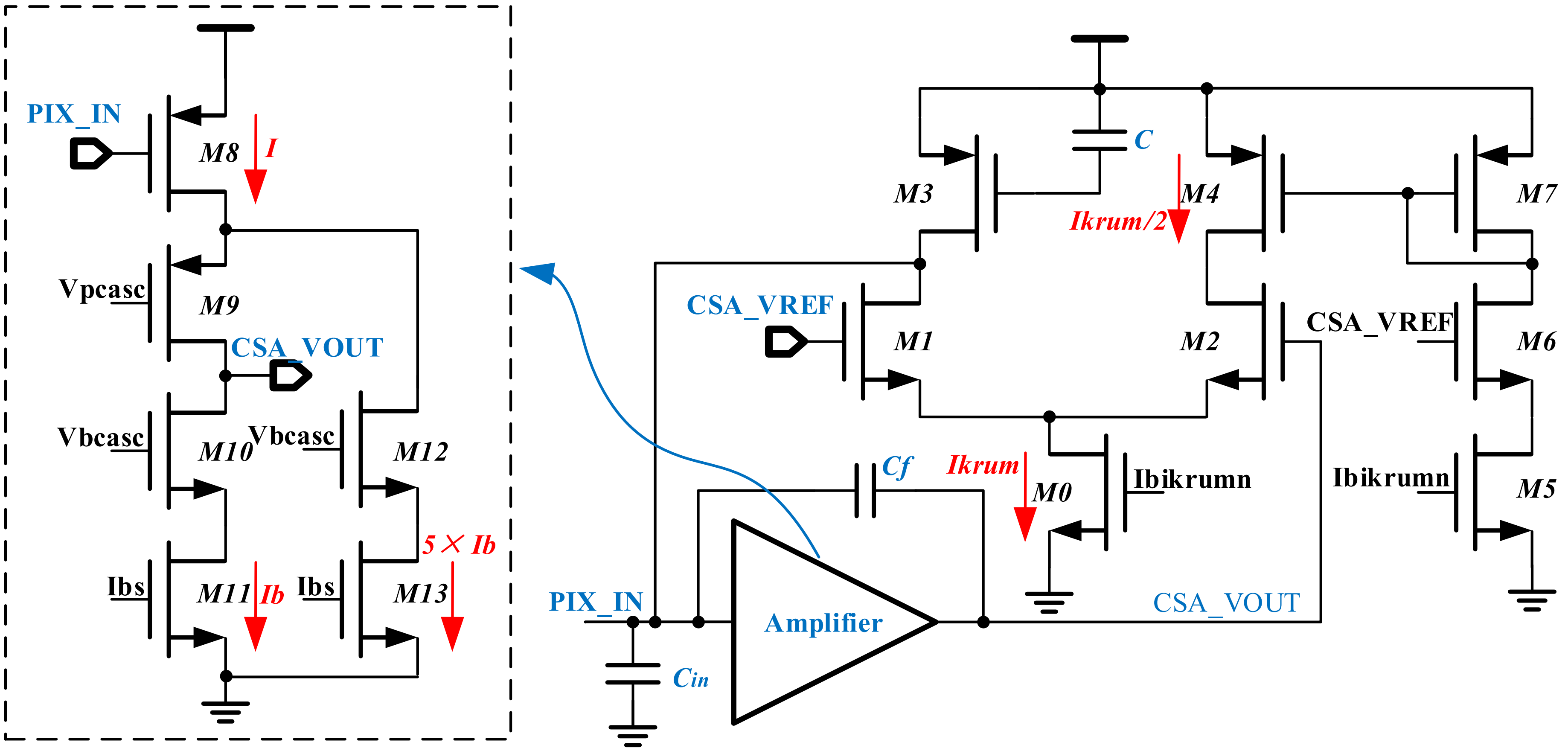


Offset spread of the CSA
Mean: 400.22 mV
Sigma: 9.27 mV
sigma/mean: 2.32%

Offset spread after AC coupling
Mean: 400 mV
Sigma: 1.11 μV
sigma/mean: 0.00026%

Activities underway: TIIMM-1 prototype

Schematic of CSA with the Krummenacher Feedback circuit



Activities underway: TIIMM-1 prototype

Dynamic range comparison (simulation) between TIIMM0 and TIIMM1 analog front-end

TIIMM-0, Pulse width of signals from Monte Carlo Simulation,

csa_vout									
	Qin/ke-	0.5	1	2	5	10	50	100	200
	Mean/ns	395.8	490.1	751	1434	2208	6274	9810	4083
	Sigma/ns	85.03	115.4	228.2	474	749.1	2023	2882	840.8
	Sigma/Mean	21.48%	23.55%	30.39%	33.05%	33.93%	32.24%	29.38%	20.59%

TIIMM-1, Pulse width of signals from Monte Carlo Simulation,

csa_vout									
	Qin/ke-	0.5	1	2	5	10	50	100	200
	Mean/ns	282.8	596.6	924.4	1957	3818	14290	23820	37100
	Sigma/ns	18.72	30.73	67.47	178.6	358.8	1379	2304	3559
	Sigma/Mean	6.62%	5.15%	7.30%	9.13%	9.40%	9.65%	9.67%	9.59%

Pulse width spread vs Qin(500e-~200ke-)

For the pulse width of signal csa_vout, the mean value and the sigma value increases with the Qin from 1ke-, and the value of sigma/mean seems to saturate 10% in TIIMM-1 after optimization.

Deliverables and milestones status

June 2019 · June 2020 · June 2021 · today · June 2022

3.1.2 TIMING OF THE DIFFERENT WORK PACKAGES AND THEIR COMPONENTS

Work package number	JRAx
Work package acronym	TIIMM
Work package title	**T**racking and **I**ons **I**dentifications with **M**inimal **M**aterial budget

TASKS/Subtasks	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1 Sensors and final device requirements definition																
1.1 Sensors and final device requirements definition																
Task 2 Sensors design																
2.1 Design of the first sensor prototype																
2.2 Design of the second sensor prototype																
Task 3 Production of the sensors																
3.1 Production of the first sensor prototype																
3.2 Production of the second sensor prototype																
Task 4 Preparation of the test set-up																
4.1 Preparation of the first sensor test set up																
4.2 Preparation of the final device test set up																
Task 5 Testing and reporting of results																
5.1 Testing of the first prototype																
5.2 Report on the first prototype obtained performances																
5.3 Testing of the second prototype (multisensor device)																
5.4 Simulation and modelling of the performances																
5.5 Report on the possibilities for PID from the results																

(Timelines are indicate in grey, milestones with black boxes)

MS60

Deliverable D27.2 - MS62

Deliverable D27.1 – MS61

Summary: difficulties, delays, future plannig

- **Task 3.1**: Production of the first sensor prototype accomplished in time
- **Task 5.1**: Testing of the first prototype accomplished in time (**results not fully satisfactory**)
- **Task 3.2**: TIIMM1 sensors production

  Design of the three versions (TIIMM0new, TIIMM1-A, TIIMM1) ready

  Submission to Silicon foundry those days (novembre 2021)

  Turn around longer due to semiconductor crisis (6 instead 4 months)

  Cost of the submission increased due to semiconductor crisis
- **Task 4.2**: Preparation of the final test setup started october 2021 (**supposed ready Q3 2021**)

  Sensors testing PCB board design started (production start january 2022)

  Readout board based on Terasic ADC-SoC-P0435 board (available) – firmware under development
- **Task 5.2**: Testing of the second prototype (**start planned for june 2022, supposed Q4 2021**)
- One talk given at **PSD 2021** and one submitted at **VCI 2022**

A 6 months prolungation of the overall project would be highly desirable